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**Improved Quick Disconnect (QD) Interface Through  
Fail Safe Parts Identification**

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# **Improved Quick Disconnect (QD) Interface Through Fail Safe Parts Identification**

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## **Abstract**

**An extensive review of existing Quick Disconnects (QDs) mating and demating operations was performed to determine which shuttle part interface identifications and procedures contribute to human factor errors. The research methods used consisted of interviews with engineers and technicians, examination of incident reports, critiques of video and audio tapes of QD operations, and attendance of a Hyper QD operational course. The data strongly suggests that there are inherent human factor errors involved in QD operations. To promote fail-safe operations, QD interface problem areas and recommendations were outlined and reviewed. It is suggested that dialogue, investigations and recommendations continue.**

## **Introduction**

**Kennedy Space Center's Space Shuttle Program is engaged in a large scale effort to systematically analyze, understand and mitigate safety risks induced by human factor errors. The Industrial Engineering for Safety (IES) program is given the responsibility of designing safety upgrades as well as verifying the safety of large and complex systems. Historically, the focus on safety was primarily on improving flight safety by changing flight hardware. Currently, the focus is on reliability of flight hardware and the reduction of catastrophic failures due to flight hardware critical failure modes, accepted risk hazards, flight and ground safety risks caused by human error during processing, and handling and manufacturing of flight hardware.**

**The reliability and safety of flight systems is dependent upon human characteristics and the dynamic interactive factors involved in man-machine interface. The consequences of human errors are very diverse and can range from damage to equipment and property, injury to personnel, fatalities, and disruption of scheduled system operation. All represent a significant cost to the space program. To minimize human error, we must seek to reduce the frequency of occurrences and diminish the impact of such occurrences. To accomplish this, we can implement new and better measures to prevent repetitive occurrences.**

**The focus of this paper is on improved hardware interface with quick disconnects through fail-safe parts identification. The frequency and types of problems encountered with quick disconnect mismates will be provided. Finally, this paper will provide recommendations for the improvement and fail-safe of quick disconnects.**

## **Background**

**Past experience revealed that the task of mating and demating quick disconnects (QD) resulted in incidents due to numerous human factor errors and the poor interconnection of environmental conditions (i.e., industrial design, workspace design, and display design). For example, there have been a number of occurrences in which technicians inadvertently mated ground half coupling (GHC) QDs to the wrong air half coupling (AHC). Furthermore, technicians are consistently required to perform a series of QD mates and demates involving similar nomenclature identification and have mentally transposed the system code and mismated the QD.**

**Apparently, there is a need to improve QD mate/demate operations under the current industrial designs. A major accident has not occurred, however, the potential does exist for both human injury and flight hardware damage to the Orbiter. Consequently, with the recent rise in the occurrence of incident rates, this research project focused on identifying the root causes of error in parts identification and providing recommendations for corrective action to resolve human factor errors.**

**This project involved an extensive review of existing QD operations as well as pre-existing problems that have been documented from 1995 to the present. For this reason, the following objectives were established to investigate QD mate/demate procedures and to evaluate current practices relating to Orbiter Maneuvering System Reaction Control System (OMS RCS) QD operations.**

**Study Objectives were to:**

- 1) Determine which shuttle processing interfaces QD can be improved by the fail-safe concept.**
- 2) Provide recommendations on how to improve the QD interfaces. Recommendations will not violate policy and procedures regarding Safety, Environmental, Current Union Agreements, and NASA regulatory requirements. Recommendations will support existing shuttle processing contracts and guidelines established in support of Orbiter/GSE processing.**

**This ten week effort concentrated solely on the above objectives, however, continual dialogue through investigations and recommendations will continue.**

## **Methodology**

**The methodology used in this project included: an investigation of QD operational procedures, interviews with engineers and technicians, examination of incident reports, observation of video and audio tapes and attendance of a Hyper QD class. Each of these methods is presented in more detail in the following section. Given the limited time to accomplish the objectives of this project, the research techniques utilized were designed to obtain results in a timely manner.**

**Methods used to identify QD problem areas were:**

- 1) Interviews focusing on identifying recurring problems associated with QD mates. Questions were posed to technicians and engineers involved with QD operations at Kennedy Space Center, and the respondents included teams from NASA-KSC engineers and technicians, and USA Industrial Engineers and Human Factors personnel.**

**Questions were designed to assess the impact of environmental factors on human factor error in part identification of QD mates during processing and maintenance of the Orbiter. Knowledge gained from such interviews was used to confirm and clarify data from the following sources.**

- 1) Incident reports (White Paper Reports) generated by USA ground operations safety reporting.**
- 2) Documentation of PR and OASIS reports with close call consequence ratings for potential damage to major essential flight elements.**
- 3) Video and audio taping of actual QD operations.**
- 4) QD operations during the course LSC 590 Hyper QD installation.**

**These research methods provided insight into incidents within QD operations. Problems and recommendations are categorized into the following areas:**

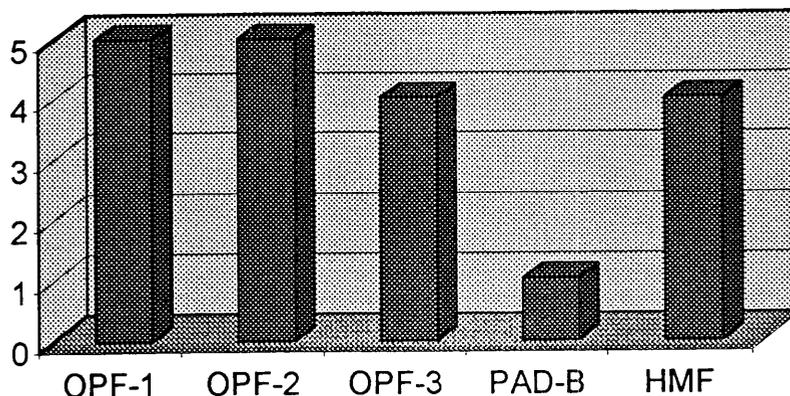
- 1. Industrial Design**
- 2. Display Design**
- 3. Task Design**
- 4. Team Communication**
- 5. Distractions**
- 6. Cognitive Processing Errors**

## **Results**

**The primary findings from interviews and incident reports reveal that numerous errors are encountered with QD during operations. Interview data is summarized in the conclusions and recommendations section and is presented in the format of problems (P) and recommendations (R). Inspection of the data from incident reports dating from 1995 to 2001 supports the interview data that**

human factor errors do occur while mating and demating QDs. The chart provides a summary of documented errors with the frequency and facility location.

### Errors While Mating and Demating Air Half Couplings



#### Conclusions and Recommendations

##### Summary of Human Factor Problems/Errors Contributing to QD Mismatch Interface and Suggested Recommendations

P – problem  
R – recommendation

##### ➤ Industrial Design

###### Poor visual indicators and numerical markings

- Although Rockwell documented in 1981 that the existing QD numbering system was easy to confuse, we are still experiencing the following problems associated with QD numbers:

**P – 1** Size of lettering in numbering system is too small.

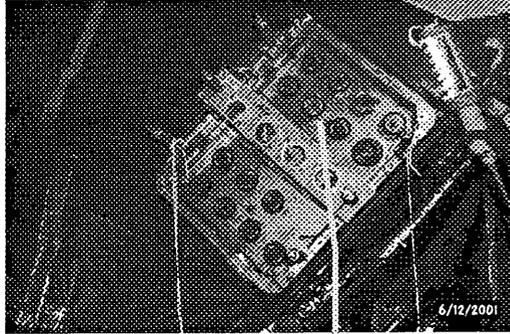
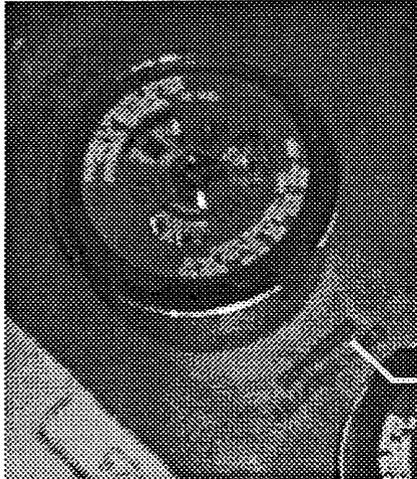
**R – 1** Numbers must be large enough and visually clear on door panels and QDs.

**P – 2** Some numbers are erased or faint as a result of fuel leakage

**R – 1** Improve the current maintenance program

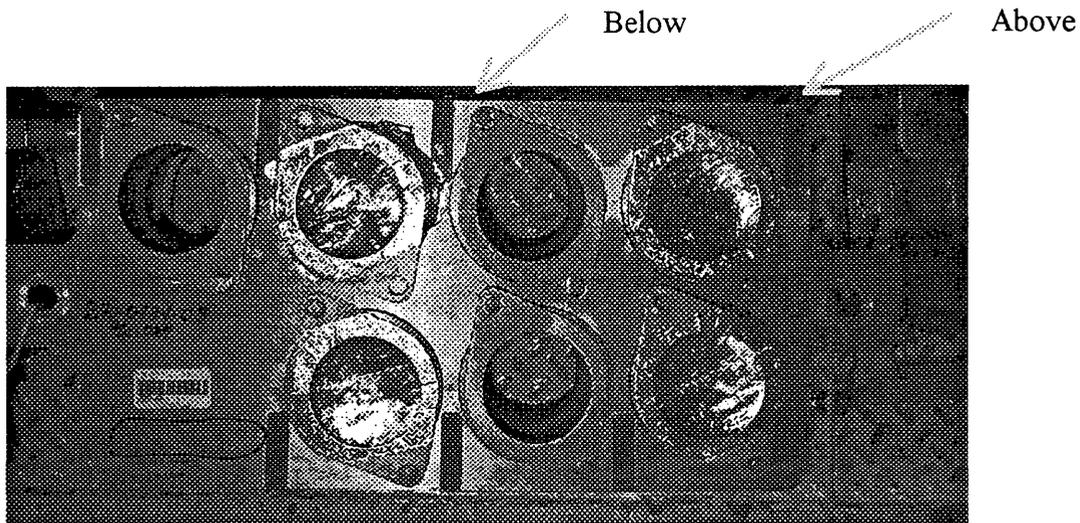
**P – 3** Engraved numbers are not visually clear on door panels and at times, depending on the set up, can be difficult to read.

**R – 3** Collect data of each panel and analyze



MD  
223

**P – 4 Numbers are not consistently stationed at the same location (i.e., sometimes numbers are above the QD, sometimes below the QD).**

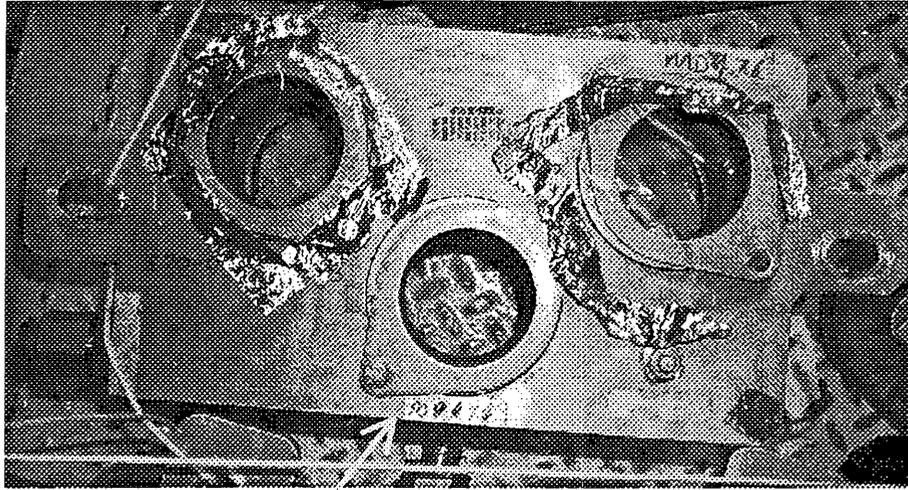


***R – 4 Evaluate and standardize, with consideration of horizontal and vertical processing***

**P – 5 Poor illumination during some QD positioning**

**R - 5 It is essential that appropriate illumination during all QD operations and positionings be maintained. Perhaps head mounted telescopic lighting would provide more direct illumination.**

**P – 6 Scupper Identifications are at times missing or not available and are not clearly marked. The following picture shows the QD numbers being marked with a marker.**



***R – 6 Appropriate Scupper identification must be provided and maintained. Engineers should conduct a pre-task walk down to verify and insure that all scuppers are appropriately identified.***

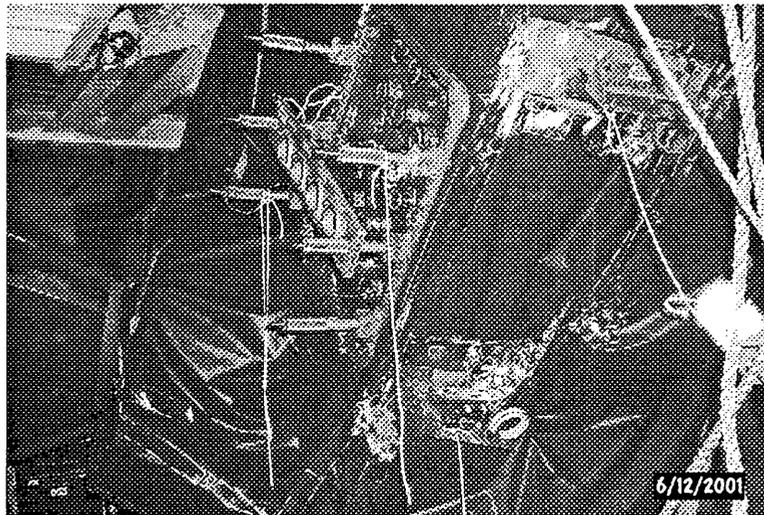
**P – 7 Before installing the GHC, the technician needs to confirm the AHC number with the scupper number, usually with a flash light. Scupper numbers have different layouts and if the technician does not confirm with the AHC this could lead to a mismatch.**

***R-7 Standardize the layout of scupper tagging to reduce the confusion to a minimum.***

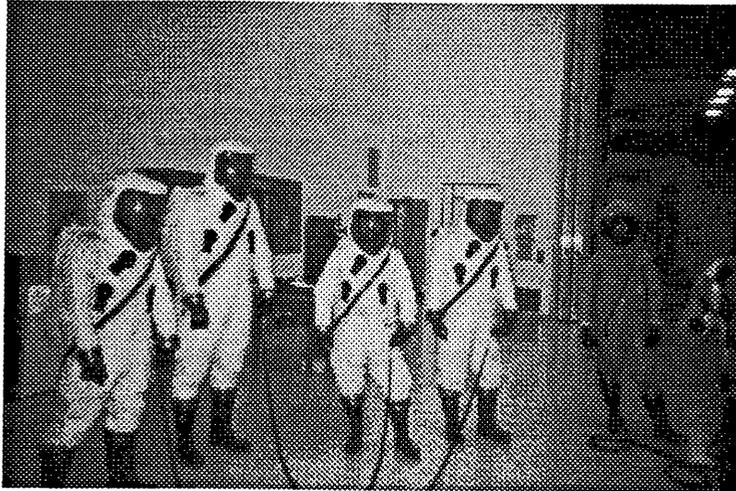
**P – 8 Obstructions to installing the QD, (example: lanyard in way).**

***R – 8 Obstructions towards the installation of QD's should be designed out of the system.***

**Some workspace positions have inherited poor illumination and at the same time may be difficult to reach. Note picture illustration:**



**P – 1 The SCAPE suit inhibits visual perception as well as normal tactical and dexterity operations.**



***R – 1 Pre-task walk down and labeling should reduce the chance for making mistakes.***

➤ **Display Design**

Dual coding system often causes Technicians to inadvertently perform mismates. The following GHC QDs, located at the designated purge header panel, are a dual purpose QD and promote human error during interface connections with the Orbiter: The majority of these dual purpose QDs are mated to the AHC at the same Orbiter door.

<b>Purge Header Panel</b>	<b>Dual Purpose QD</b>	<b>Orbiter Door</b>
<b>Panel S70-0865-22</b>	<b>MD311/511 MD307/507 MD309/509 MD313/513</b>	<b>56-34/56-36 59-22 59-22 59-22</b>
<b>Panel S70-0865-24</b>	<b>MD212/412 MD208/408 MD214/414</b>	<b>56-09/56-13 59-21 59-21</b>
<b>Panel S70-0865-26</b>	<b>MD213/413 MD209/409 MD211/411</b>	<b>59-21 59-21 56-33/56-35</b>

***R - 1 Initiate practical means of change to re-identify the AHC and GHC QDs that will be fail-safe.***

***R - 2 Ideally, visual cue in the form of color-coded tags and/or symbols to facilitate QD identification when dual coding systems are being used.***

- **A colored tie wrap, or some other method of tagging, could be used to alert the Technician of dual purpose QDs. This extra cautious measure will aid the technician toward preventing a mismatch.**
- **The engineer should read only the designated QD number that is to be mated, and caution! the Technician of the likelihood of a mismatch.**

**R - 3 For operations involving dual purpose QDs the OMI instructional manual should be modified to read only the intended QD. Change the procedures to list only the QD number that is connected to the work step. This change will limit the possibility of the wrong QD number being called out when connecting to the vehicle.**

**Sequence steps should read as follows for example:**

**“verify GHC MD 215 to AHC MD 215”**

**instead of:**

**“verify GHC MD 223/215 to AHC MD 215”**

**R - 4 Cover all flight caps if not in use during the ongoing operations. Currently tape is widely used to cover unused holes, possibly there could be a better design rather than tape to accomplish this. Also notice that the Door number 59-10 is marked with a marker and is not permanently tagged.**



**Similarity in the QD nomenclature has caused and contributed to human errors.**

**P - Technicians transpose similar ID numbers. To mention a few examples:**

- Technician vented GN2 into the test cell MD-707, should have vented through outside scrubber system MD-107.**
- Technician inadvertently demated and mated to the wrong purge header. Tech was requested to demate MD164 from AHC164. The Tech inadvertently demated MD124 from the vehicle.**

**Note: See Result Section for full list of documented mismates recorded for the past 10 years.**

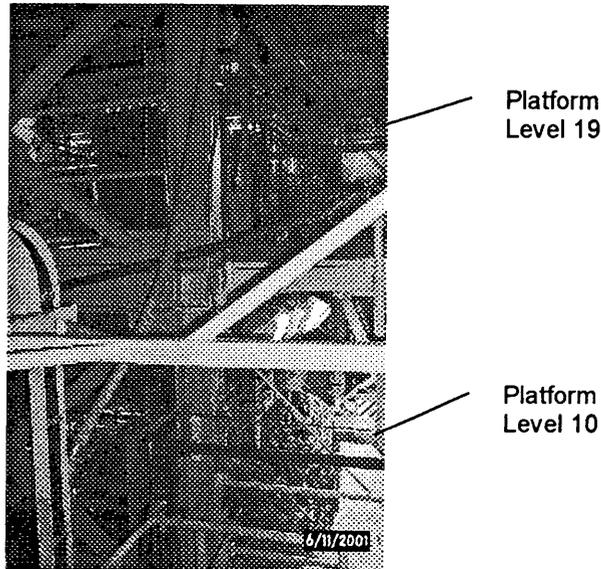
**R - Engineer should do pre-task operations and designate those QDs to be mated/demated.**

***R - Engineer must require Technician to repeat, more than once, and verify QD operations. Should reinforced at the OIS Discipline Course/Training.***

***R - Perhaps a second designator such as a letter or symbol can be used along with the ID number.***

➤ **Task Design**

Technicians often are required to leave one floor level to mate a QD after receiving commands from the System Engineer at a different floor location.



**P - 1** Hearing commands information and having to walk to another level to perform the operation increases human error.

***R - 1*** Engineers must call commands in appropriate sequence with the panel and floor level in consideration. By performing a walk down before the actual operation, the engineer would have a better understanding of the floor levels where the operation is taking place.

**P - 2** Interruptions between a given command and performing the task increases human error.

**R - 2** All Technicians working the QD operations must verify the QD operations.

➤ **Team Communication**

**Lack of Task Team Pre-Briefing**

**P - 1** Engineer often do not perform a thorough walk down to check and verify the configuration sight prior to QD operations

***R - 1*** Engineer must conduct a walk down of the area to survey QD numbers, Orbiter door locations blanking plate requirements, and platform levels prior to the operation and make appropriate designations necessary.

**P - 2** Engineer may not review OMI prior to the QD operations to ensure that all steps are feasible

**R - 2 Engineer should take the time to read the command operations prior to pre-briefing.**

**P - 3 Engineer may or may not perform a pre-task briefing to insure that Technicians understand the nature of operation and understand the "big picture"**

**R - 3 Provide pre and post-briefing sessions. The bottom line is to improve communication between the Engineer and the Technicians.**

- **Engineer must conduct a pretest briefing session prior to the Technician performing the QD operations. A general-purpose statement at the beginning of each sequence to describe the task is warranted. In addition, during the pretest briefing, visual reinforcement of the operation would further improve the understanding of the operations.**
- **Utilize morning safety briefing as a forum for incident/error prevention discussions.**

➤ **Team Communication less than adequate:**

**P - 1 Technicians may not acknowledge System Engineer commands by performing call back verification**

**R - 1 Require Technicians to verify operations. (OIS Discipline)**

**P - 2 Door designation may not be called out between operations (i.e., tech during the mating operations may assume an incorrect QD designation)**

**R - 2 Engineer should not precede to the next command until QD operation is verified/affirmed by the Technician.**

**P - 3 Head set may filtered in background noise from the high bay**

**R - 3 Assemble Engineers and Technicians for team discussion to critique their QD operations. Discuss and listen to the OIS tape of the task.**

**P - 4 Engineer may read the work instructions a little too rapidly at times**

**R - 4 Technicians should not hesitate to ask for instructions to be read slower or repeated for clarity.**

**P - 5 Engineer may not communicate all the necessary information needed for the Technician to make the right decision on which QDs are to be connected. (Note also the confusion created due to the dual use of QDs)**

**R - 5 Utilize lessons learned sessions to communicate to the workforce the necessity for good test discipline at all times. It is apparent that there is a need for the Engineer to check panels prior to QD operation and conduct a walk down before conducting pretest briefing procedures with Technicians.**

**P - 6 Work steps are not written clearly.**

**R - 6 Insure that all work steps are written clearly.**

➤ Operational Team Support May Lead to Human Error

**P - 1** In the crotch area of the OMS pod, when another technician is assisting and wearing the headset, call out steps from the platform may not be all inclusive for the technician performing the QD operation.

**R - 1** *When Technicians are out of the range for connected headphone, wireless headphone must be provided. Engineer must give door location along with crotch area description.*

**P - 2** Technicians may be relieved to take a break while the two new technicians may not receive sufficient pre-briefing.

**R - 2** *Try to schedule break with shift change. Technicians are to complete the task prior to change of shift. Allow for shift overlap to brief oncoming Technicians of the current task.*

- *Improved task team discipline*
- *Face to face Hand-offs tie-ins are a must.*

➤ Distractions

Technician can be interrupted during QD command operations. To mention some examples:

**P - 1** Outside background bay noise

**R - 1** *All outside bay noise must be eliminated where possible. Engineer must brief all personnel involved in QD operations to reduce as much as possible any confusion or interference that may be attributed to outside noise.*

**P - 2** Working on several tasks simultaneously

**R -** *Technicians are to work on operations in sequential order and verify all operations.*

**P - 3** Interruptions from other technicians needing the work area or asking questions concerning another QD operation.

**R - 3** *Get rid of all distractions and interruptions. QD operations are too critical for distractions to interfere with operations*

**P - 4** Working steps out of sequence:

- Working more than one QD installation with same suit set up
- Working series of single steps with out verifying QD operations

**R - 4** *Technicians are to work on operations in sequential order and verify operations. Simultaneously working on several QDs operations should not be permitted. Such activity causes attention to focus away from the immediate task.*

➤ Cognitive Decision Processing Error

Similar ID numbers (GHC MD 711, GHC MD 707, AHC MD 111, AHC MD107 and GHC MD 107) on QD are often transposed when making the QD mate. These particular QDs nomenclature have lead to numerous incidents and have contributed to a majority of the incidents/accidents occurrence. Previous citations by USA (1996) QD Mate/Demate Accuracy Team and an outside Human Factors consulting group hired by Rockwell International (1981) have previously

confirmed this as a contributing cause. The following is a list of GHC OMS QDs that are often identified as having similar nomenclature:

Purge Header Panel	Dual Purpose QD	Orbiter Door
Panel S70-0865-02	MD117 MD711 MD111 MD147 MD157 MD127 MD137	28-13....
Panel S70-0865-04	MD106 MD126 MD128 MD138 MD148 MD158	28-00 28-12....
Panel S70-0865-20	MD314/514 MD310/510 MD308/508	59-22....

**P - 1** Technicians may check designations and look away from the reference point and still transpose numbers wrong (i.e., seeing the number 3 instead of the number 5). Tabulation of these QD incident provide insight into the types of occurrence and the frequency of the occurrence which is illustrated in the preceding result section.

*R - 1 Technicians must maintain focus*

**P - 2** Technician may not work specific task and may not be knowledgeable of the specific QD operation.

*R - 2 When similar nomenclature ID numbers are being mated and demated, the Engineer should perform pre-task operations by marking the appropriate the QDs and panels to be used.*

## Summary

Human errors and the catastrophic failures produced by them will continue as long as there are human-machine interactions and as long as we fail to understand the psychology behind human failures. It's a nontrivial task, one that involves understanding how humans learn, how we deal with process sensory inputs among numerous others. The cognitive processes that enable unique human capabilities also make humans vulnerable to certain forms of errors. The good news is that error rates can be reduced by redesigning external factors to reduce vulnerability to error and by designing systems and procedures to assist recovery from error.